Can instruction on engineering design be given on CD-ROMs? Questions and discussion accompanying a demonstration of MIT's EDICS

David Gordon Wilson
Massachusetts Institute of Technology

SUMMARY

The reasoning and background that led to the development of a multimedia system aimed at supplementing instruction in engineering design are described. The usefulness of the resulting program, necessarily one of restricted scope, has been limited by the technology available. The advent of CD-ROMs promises the first opportunity of testing the effectiveness of multimedia instruction because most of the restrictions on use by instructors and students are eliminated. The contents of the present MIT multimedia program are briefly described. Questions on how the technology might be developed and used are posed and discussed.

BACKGROUND

The purpose of EDICS (Engineering-Design instructional Computer System) is to improve the preparation of students to tackle design projects. Today's incoming students are mostly not people who have grownup mending cars and working in machine shops, as was the case twenty-five years ago. My design colleagues and I have been repeatedly shocked to find that bright students who have spent four years at MIT passing all their classes, including the sophomore design class(es), can do no better in the senior design-project class than to produce cartoons rather than engineering drawings. Often they are of devices that cannot be assembled. If they use bearings, fasteners, power-transmission devices and so forth they are often wildly inappropriate. We are now accustomed to students coming up after a design lecture to ask what is a flange, a shaft, a washer and so on - terms that we naively thought were part of the common language. In fact, we used a language analogy to illustrate the dilemma in which we were putting these students: it is as if we were asking them to write a novel in German when they had no idea of German words or grammar[1].

We must therefore provide some knowledge of the words and grammar of engineering. Yet the curriculum is already over-fill. We cannot add more demands to overburdened students and faculty. We want a resource that could be used to save time, rather than to take time, when design questions and problems arise. The team (acknowledged later) that developed EDICS searched unsuccessfully for suitable textbooks. We decided that even if we had the capability of writing the perfect textbook on introductory design it could not meet the need. A presentation that included clear video that could be randomly selected coupled with computer animations and as much user challenge as possible seemed to be the best that could be considered. It would clearly be second best to having students work in a hardware apprenticeship: the experiences would be vicarious, but in the circumstances lifelike ("virtual-reality") experience with the components of design is far better than none.

The answer to the question asked in the title of this paper is highly dependent on technology. We started initial development of EDICS in 1983-4, at a time when available multimedia systems were painfully slow and " confining. Later (1988) we received partial funding by the NSF at a propitious time: just before the announcement by Macintosh of the development of HyperCard. The creativity of our students and faculty was thereby given freedom, and much of the content of our present CD-ROM was developed under HyperCard. Using the system was still quite forbidding, however. We had to assemble a large-memory Macintosh and a laser-disk player and to show the program on the computer monitor and a neighboring TV monitor, viewable by only a small group. We fitted everything into a heavy lockable rolling steel cabinet, theft being a constant concern, and took the whole setup to design labs and workshops and very occasionally to classes for use with and by small groups of students. It was difficult to make such a system available to students for private study or to faculty for use in classrooms. The program took so long to load and to set up that we had to dedicate a complete system entirely to EDICS. David Crismond, a doctoral candidate in the Harvard Graduate School of Education, carried out what we believe is the first comparative test of multimedia instruction versus test[2]. Despite what seemed likely to be penalizing disadvantages to the manner of use of EDICS, it was preferred by the test population of students, particularly by those who were inexperienced in engineering hardware - the target users - and test results were slightly better for students using EDIC S than for those using the-equivalent text. (The two principal penalties to EDICS were that the tests excluded anything that involved animations or video, because these could not be treated in the text; and that the tests were based on a small part of EDICS and an equivalent small number of pages of text. Computer systems have a large advantage over text when dealing with a large mass of information, as is typical of design problems). EDICS could be considered to have won the battle but, because of technological limitations, to have lost the war.

The development of low-cost CD-ROMs and effective computer-fed projectors has enabled multimedia to be used with relative ease by instructors in computer-equipped classrooms and by students in their personal computers. The School of Engineering, MIT, and its part of the ECSEL coalition, funded Center Vision (a Woburn, MA MIT-spinoff company headed by Seichi Tsutsumi) to produce a CD-ROM with the existing EDICS content presented on a single (Macintosh) screen.

The following brief description of the principal contents of the EDICS CD-ROM will lead to the questions indicated by the paper title.

PRINCIPAL CONTENTS OF EDICS

There are at present four sections. We chose them because we considered that useful instruction in these topics would yield the maximum improvement in the design capability of our graduating seniors.

Sketching and drawing: about one third of incoming freshmen have had drawing in high school. The needs of the other two-thirds are normally taken care of by one or possibly two lectures by an inspiring instructor and a collection of notes taken from the EDICS screens. The multimedia presentation is particularly effective, we feel, because a photograph of an artifact (a pillow-block bearing) is replaced by an isometric sketch that clearly shows the relationship. This is then rotated to face the viewer, cut by sectioning planes, viewed from the different orthogonal directions, projected onto planes, and so forth to make both multiview and isometric drawings understandable. Sufficient treatment is given of dimensioning and tolerancing for the needs of students in senior design projects.

Bearings: the purpose of this (and subsequent) sections is to enable users to choose the appropriate types of, in this case, bearings for a design project, rather than to design the bearings themselves. We adopt an innovative approach in proposing a universal definition of a bearing; defining it in terms of the degrees of freedom in which it constrains relative movement; and classifying it among four possible mechanisms that provide the constraining forces (sliding, rolling, flexure and non-contact means).

Mounting of rotors and levers on shafts: we define a "torque-capacity ratio" (TCR) as the proportion of the material-failure torque that the mounting or coupling must provide and give many examples of different methods providing different levels of TCR. We also specify speed, size and torque level as necessary inputs, and provide a selection system. We challenge students with tests of knowledge or of estimating ability, as in the other sections. We show examples ranging from fishing-reel handles to race-car wheels.

Joining and capping cylinders: in this section "cylinders" includes pipes, tubes, engine blocks, cylinder heads and many other examples. We ask questions intended to be challenging, such as "why do we screw the tips of mechanical pencils into the pencil bodies, but we don't screw church steeples into the building towers?' We use a lawnmower engine, an engine for a model airplane, and many other artifacts as examples.

QUESTIONS ON THE USEFULNESS OF CD-ROM FOR ENGINEERING INSTRUCTION

L Does "virtual reality" lead to "reality"? In other words, will students who become acquainted with engineering through multimedia become proficient in real-life engineering? We hope that the answer is "yes": there are many examples of highly successful engineers who taught themselves from books, and the added dimensions of moving videos and animations cannot detract from the reading experience.

2. **Will technologies such as CD-ROMs supplant books and papers?** This author believes that this will not be the case, even though there are visionaries who claim that in a few years book publishing will be largely over, and even though the proceedings of this conference will be put on a CD-ROM. In the case of this conference, it is intended that papers be printed from the CD-ROM, which is an acknowledgment that most people prefer to read from text on paper rather than on a screen. Multimedia programs are so expensive to produce, because of the need for a highly skilled production crew, that they will supplant texts only when there is a clear strong advantage for their use.

3. Should an instructional CD-ROM include on-screen text, eschew on-screen text (substituting voice), or supplement a printed text? The present EDICS CD-ROM has, we believe, too much on-screen text. In a new version of EDICS on which we have been working we give the user the choice of having on-screen text or speech. Speech has the disadvantage of being slower to comprehend and of irritating nearby people unless headphones are used. On the other hand, speech can be a faster means of communication if it is describing an on-screen artifact or video. The viewer can concentrate on the artifact without having to switch from text to representation and back. The concept of a CD-ROM supplementing a text is attractive for fairly short texts. However, in design one needs to have available the contents of one or more large handbooks. There is great attractiveness in having all such material on one small disk and, in particular, having one index or search routine to cover, at very high speed, all the material.

4. **Can a CD-ROM provide all the (non-hardware) material needed for a full course?** This is an intriguing question which we (principally Seichi Tsutsumi and the author) are trying to answer. It is relatively easy to draw up a proposed sequence of lecture topics and to link these with appropriate examples for presentation in class and with topics lists for the students' homework assignments. If these are supplemented with problem sets in the CD-ROMs one must expect that students would prepare model answer books ("bibles"). The problem sets

would be similar to questions at the end of textbook chapters, and instructors know that it is usually effective to change these problems somewhat to discourage copying from bibles, and the same will be the case for problem " sets on CD-ROMs. (The assumption is that the same CDs will be given or sold to the students as to the instructor(s). Alternatively an instructors' text could contain pedagogical suggestions, but the embedded linking of examples would be lost).

CONCLUSIONS

The use of CD-ROM technology seems to promise a place for the treatment of engineering-design instruction, at least as a supplement to text and lectures and as a necessary substitute for actual hardware experience (to which it is hoped that this vicarious experience will lead). The very high cost of production will limit its use to those situations where it has a clear advantage. Design instruction maybe one of these. The EDICS program is a first imperfect step towards more-effective design multimedia. The author and his associates hope to be able to produce an improved version that will go some way in the directions recommended in the discussion.

ACKNOWLEDGMENTS

Funding for the development of EDICS came from (in sequence) Project Athena, MIT; the National Science Foundation; the ECSEL coalition grant from the National Science Foundation; the Center for Advanced Engineering Studies, MIT; and the School of Engineering, MIT. The original suggestion for EDICS was made by Seichi Tsutsumi, then at MIT, who has worked with the team throughout. Professors Ernesto E. Blanco and Woodie C. Flowers contributed to the initial approach, and Emesto Blanco has continued to produce beautiful sketches and other inputs. Much of the work was done by three creative and hardworking graduate students and by a large number of equally creative undergraduates working on UROP (Undergraduate Research Opportunities Program). The author acknowledges his debt to all.

REFERENCES

[l]Wilson, David Gordon and Ernesto E. Blanco (1991) "EDICS: a multimedia tutor for engineering design"; MECHANICAL ENGINEERING vol. 113 no. 10, ASME, NY, NY.
[2]Crismond, David P. and David Gordon Wilson (1992) "Designing an evaluation of an interactive multimedia program: assessing MIT's EDICS", Frontiers in Education Conference, Nashville, TN.

BIOGRAPHICAL INFORMATION

DAVID GORDON WILSON received his formal education in Britain. He came to MIT and Harvard on a post-doctoral Commonwealth Fund fellowship 1955-57. Subsequently he returned to work in the gas-turbine industry in Britain, and later taught mechanical engineering in Nigeria. Before coming on the faculty at MIT in 1966 he was technical director and vice president of Northern Research& Engineering. in London and Cambridge, MA.